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STATISTICAL ASSESSMENT OF THE XM40 MASKS AND US-10 RESPIRATOR

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December 1985

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US ARMY BALLISTIC RESEARCH LABORATORY
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The Chemical Research and Development Center (CRDC) asked the BRL to conduct an independent analysis of the data obtained from the Engineering Design Test (EDT-2G) of the XM40 series protective masks and British US-10 respirator. This analysis is one of many analyses from which results were used to determine if the masks are reliable enough to enter into the next phase of testing, DT II/OT II. Several problem areas have been identified from the analyses of the tests performed on the Scott and ILC masks, and the US-10 respirator. (Cont.)

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20. ABSTRACT (Cont.)

The most serious problems seem to have been corrected, therefore, the Readiness for Test Review (RFTR) committee has decided to allow the masks to enter DT II/OT II testing. Keywords:

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

I. INTRODUCTION

The Chemical Research and Development Center (CRDC) asked BRL to conduct an independent analysis of the data obtained from the Engineering Design Test (EDT-2G) of the XM40 series protective masks and British US-10 respirator.

The evaluation of this data is based on minimum requirements set by the revised Joint Service Operational Requirement (JSOR), and the test procedures were approved by the Test Integration Working Group. The background information and detailed descriptions of the masks and tests can be found in reference 1.

This analysis is one of many analyses where results will be used to determine if the masks are reliable enough to enter into the next phase of testing, DT II/OT II.

II. MASKS

Three types of masks were evaluated. Two masks were from the XM40 series, which will be referred to by their manufacturers names, Scott (Aviation) and ILC (Dover). The third mask was a British US-10 respirator manufactured by Avon and will be referred to as simply US-10. The number of available masks from each manufacturer was: 110 from Scott, 110 from ILC, and 100 from US-10.

III. TESTS AND ANALYSES

A. INSPECTION TESTS

Inspection tests were performed on all masks prior to any other test. The inspection tests were the dioctal phthalate (DOP) leakage test and the inhalation and exhalation resistance tests on unpackaged masks. Haze, light transmission, and Ann Arbor (distortion) measurements were recorded and analyzed on the lenses.

1. DOP Leakage Test

The requirement set for the DOP leakage test is: no more than 0.003 percent of the DOP is permitted to leak into the masks. Only the amount of leakage beyond the .003 percent level was recorded. Levels of leakage that met the requirement were recorded with an "O.K." Because of this recording procedure, the point estimate of reliability was based only on the pass rate, i.e., the number of masks passing the DOP leakage test divided by the total number of masks on test.

Table 1 gives a summary for each manufacturer of the number of failures (F), number of successes (S) (number of masks that passed the requirement), the total number of masks on test (N), the point estimate of reliability (R), and the lower confidence limit (L.C.L.) on reliability at 80% confidence.

TABLE 1. INSPECTION DOP LEAKAGE TEST
Requirement: .003% maximum

MASK TYPE	F	S	N	R	L.C.L on R. @ 80% CONF.
SCOTT	50	46	96	.48	.43
ILC	0	99	99	1.00	.98
US-10	26	63	89	.71	.66

Comparing the total number of masks that went through this test (N) with the masks available for testing, we can see that fourteen Scott masks, eleven ILC masks, and eleven US-10 respirators were not tested. The reason for not testing all the masks as stated in the test plan is unknown to the authors.

The point estimate of reliability and confidence limit for the ILC mask is very high, but the reliabilities and confidence levels for the Scott mask and US-10 respirator are alarmingly low. Further investigation of the Scott mask and US-10 respirator by CRDC revealed the problems. The Scott masks were leaking around the lens area, and the US-10 respirators were leaking in the drink tube area. The designs of the Scott mask and US-10 respirator have been modified to correct these imperfections, and the discussion of these redesigned systems can be found in section IV.

Out of those masks that passed this DOP leakage inspection test, a sample of masks was taken to undergo adverse conditions. This will be explained in section III B.

2. Airflow Resistance Tests

a. Inhalation Test

The next inspection tests performed were the airflow resistance tests. This was made up of an inhalation and an exhalation test. The requirements for the inhalation resistance test of the masks with canisters are: inhalation resistance must not exceed 55mm H_20 at 85 lpm for a field mask and not exceed 70 mm H_20 at 85 lpm for a combat vehicle or aircraft mask. The XM40 masks used in the field have a different requirement for this test from those masks used in combat vehicles and aircrafts because of the placement of the canister. For the masks used in the field, the canisters are attached directly on the face of the mask, where as the masks used in combat vehicles and aircrafts have the canisters hooked to the waist and a hose connects the canister to the mask. The reason for this design difference is so that the canister does not interfere with the aiming of a gun for soldiers in combat. For the aircraft usage, a voicemitter is in the face piece for audio communication. All other components of the masks are identical. A summary of the inhalation resistance test results is given in Table 2.

TABLE 2. AIRFLOW RESISTANCE - INHALATION

MASK TYPE	F	S	N	R	L.C.L. on R. @ 80% CONF.
SCOTT					
Field	1	65	66	.98	.96
Aircraft	0	7	7	1.00	.79
Combat Vehicle	0	7	7	1.00	.79
ILC					
Field	2	65	67	.97	.94
Aircraft	0	7	7	1.00	.79
Combat Vehicle	0	7	7	1.00	.79
US-10					
Field	4	56	60	.93	.89
Aircraft	3	3	6	.50	.27
Combat Vehicle	0	5	5	1.00	.72

The US-10 aircraft masks have the lowest reliability with a point estimate for reliability of .50. There were a few failures in the field masks, however the reliability was still high. All other aircraft and combat vehicle masks were successful in passing the inhalation resistance test. [NOTE: Out of the 30 aircraft and combat vehicle type masks tested, only three masks would have passed the requirement of the field mask (i.e., 55mm H_2O at 85 lpm). Two of these masks that would have passed were manufactured by Scott and one was manufactured by Avon (US-10).]

Again, not all masks were tested and the reason is unknown to the authors. The number of masks not tested from each manufacturer is 30 from Scott, 29 from ILC, and 19 from US-10.

b. Exhalation Test

Table 3 gives a summary of the exhalation airflow resistance. The requirement states that no more than 26 mm H_2O at 85 lpm is allowed. All mask types had high reliability estimates.

3. Lens Tests

The inspection tests that were performed on each lens were: haze, light transmission, and Ann Arbor distortion.

TABLE 3. AIRFLOW RESISTANCE - EXHALATION

MASK TYPE	F	S	N	R	L.C.L. on R. 80% CONF.
SCOTT					
Field	1	65	66	.98	.96
Aircraft	0	7	7	1.00	.79
Combat Vehicle	0	7	7	1.00	.79
ILC					
Field	6	61	67	.91	.87
Aircraft	0	7	7	1.00	.79
Combat Vehicle	0	7	7	1.00	.79
US-10					
Field	0	60	60	1.00	.97
Aircraft	0	6	6	1.00	.76
Combat Vehicle	0	5	5	1.00	.72

a. Haze Test

The requirement states that the haze should not be more than 5% for each lens. The 234 pairs of lenses were well within the requirement, with the highest percentage of haze being 1.5%.

b. Light Transmission Test

The requirement for light transmission states that a lens must allow at least 85% light transmission. All 234 pairs of lenses passed with readings well within the requirement. The lowest level of light transmission was 90.1% for any lens.

c. Ann Arbor - Distortion Test

The possible readings for Ann Arbor distortion ranges from 1 to 10. A reading of 1 has no distortion, a reading of 10 has the highest amount of distortion. Any reading $\leq$ 5 is passing. The inspection test revealed that all lenses from the three manufacturers passed. One interesting observation was that all ILC and US-10 lenses had a perfect reading of 1. But the Scott lens had 23 imperfections out of 81 pairs with readings of 2, 3, or 4 . The other Scott lenses had a reading of 1.

B. ADVERSE CONDITIONS

1. DOP Leakage Test

A sample of masks that passed the DOP leakage test during the inspection phase were subjected to adverse conditions. These conditions were rain, salt-fog, sunshine, dust, and dust with DS2. After the adverse conditioning, these masks went through the DOP leakage test and the airflow resistance tests again. A summary of the DOP leakage tests is given in **Table 4**. The reliability and the lower confidence limit on reliability based on these tests are given.

TABLE 4. DOP LEAKAGE TEST AFTER ADVERSE CONDITIONS

ADVERSE CONDITION	F	S	N	R	L.C.L. on R. @ 80% CONF.
RAIN — in carrier	1	2	3	.67	.29
RAIN — no carrier	1	2	3	.67	.29
SALT-FOG	2	4	6	.67	.41
SUNSHINE	4	5	9	.56	.37
DUST	5	4	9	.44	.27
DUST + DS2	4	2	6	.33	.11

All the point estimates of reliability and the confidence levels for the adverse conditions are low. If we group these same masks by manufacturer (see **Table 5**), we see that it is Scott and US-10 that have the very low reliability point estimates. This is the same pattern that we saw in the inspection test. The Scott lens and the US-10 drink tube were redesigned because of these leakages. The analyses of the redesigned mask and respirator are in Section IV. The ILC mask has a reliability point estimate of 1.00 since all 12 masks passed the test. But the L.C.L. on reliability at 80% confidence is .87. Is .87 high enough so one might say that ILC indeed passed the DOP leakage test after adverse conditions with high confidence? This question should be answered by "mask experts" or the users.

TABLE 5. DOP LEAKAGE TEST AFTER ADVERSE CONDITIONS BY MANUFACTURER

MASK TYPE	F	S	N	R	L.C.L. on R. @ 80% CONF.
SCOTT	11	1	12	.08	.07
ILC	0	12	12	1.00	.87
US-10	6	6	12	.50	.34

2. Airflow Resistance Tests

a. Inhalation Test

The inhalation airflow resistance test was performed on those same masks that were subjected to adverse conditions. The sample size for each adverse condition was less than 10, so one failure causes the point estimate of reliability to be quite low, and likewise the L.C.L. on reliability to be even lower. **Table 6** summarizes the inhalation test results for the adverse conditions.

TABLE 6. INHALATION RESISTANCE
AFTER
ADVERSE CONDITIONS

ADVERSE CONDITION	F	S	N	R	L.C.L. on R. @ 80% CONF.
RAIN, in carrier	0	3	3	1.00	.58
RAIN, no carrier	2	1	3	.33	.07
SALT-FOG	0	6	6	1.00	.76
SUNSHINE	3	6	9	.67	.47
DUST	2	1	3	.33	.07
DUST + DS2	1	5	6	.83	.58

When the failures and successes for the adverse conditions are separated by manufacturer, the point estimates for reliability and the confidence limits are about the same for each manufacturer, but they are still low enough to cause concern. The summary is given below in **Table 7**.

TABLE 7. INHALATION RESISTANCE AFTER
ADVERSE CONDITIONS BY MANUFACTURER

MASK TYPE	F	S	N	R	L.C.L. on R. @ 80% CONF.
SCOTT	3	10	13	.77	.62
ILC	3	10	13	.77	.62
US-10	4	9	13	.69	.54

b. Exhalation Test

The results for the exhalation resistance test for the same masks that went through adverse conditions are given in **Table 8**. Not as many failures occurred but because the sample sizes were small, the lower confidence limits on reliability at 80% confidence are low enough to cause concern. The separation of the test by manufacturer is given in **Table 9**.

TABLE 8. EXHALATION RESISTANCE
AFTER
ADVERSE CONDITIONS

ADVERSE CONDITION	F	S	N	R	L.C.L. on R. @ 80% CONF.
RAIN < in carrier	0	3	3	1.00	.58
RAIN < no carrier	1	2	3	.67	.29
SALT-FOG	0	6	6	1.00	.76
SUNSHINE	0	9	9	1.00	.76
DUST	0	3	3	1.00	.58
DUST + DS2	1	5	6	.83	.58

TABLE 9. EXHALATION RESISTANCE AFTER
ADVERSE CONDITIONS BY MANUFACTURER

MASK	F	S	N	R	L.C.L. on R. @ 80% CONF.
SCOTT	0	10	10	1.00	.85
ILC	1	9	10	.90	.73
US-10	1	9	10	.90	.73

C. CRDC OPTICAL DATA - 9 WEEK STORAGE (in carriers)

Twelve masks in carriers, four from each manufacturer, went through nine weeks of storage under various environmental conditions; desert, arctic, tropic, and cyclic. The desert storage was a hot-dry climate at 125° F; the arctic storage was set at -50° F; the tropic storage was a climate with constant high humidity with the temperature set at 113° F; and the cyclic storage involved rotating the mask from one climate to the other each week so that a mask would get exposure to each climate three times over the nine week period. The design set-up is given in **Table 10**. From these twelve masks, light transmission, haze, Ann Arbor, and chromaticity (yellowness index) measurements were recorded after each week. (Week 0 means the data was taken before storage.) The criteria for these tests are listed in **Table 11**.

Using exploratory data analysis and analysis of variance, the data were analyzed to see if the tests showed a significant effect at the .05 level for each factor; week, climate, and manufacturer. From the first factor, week, we wanted to know if any of the optical characteristics (light transmission, haze, Ann Arbor distortion and yellowness) degraded from one week to the next. From the results we can state that there was no significant difference in any of the optical characteristics due to the length of time in storage.

TABLE 10. CRDC 9 WEEK STORAGE (in carriers)

WEEK	CLIMATE	MASK TYPE SCOTT	ILC	US-10
0	T D C A			
1	T D C A			
• • •	• • •	• • •	• • •	• • •
9	T D C A			

TABLE 11. OPTICAL DATA CRITERIA
(MASK ONLY)

TESTS CONDUCTED	CRITERIA
Light Transmission	$\geq$ 85%
Haze	$\leq$ 5%
Ann Arbor, Distortion	$\leq$ 5
Yellowness	None

Another question was the possibility of a significant degradation in the optical characteristics due to the climate storage of the mask. Again the results indicated that climate did not have a significant effect on any of the optical characteristics.

The third factor we examined was manufacturer. There was a significant difference in masks from the different manufacturers for each of the optical characteristics. The results are shown in Table 12. We will discuss these optical characteristics individually. For light transmission, there is a significant effect due to the manufacturer. ILC, Scott, and US-10 are significantly different from each other. But if one looks at the means and the respective standard deviations (S.D.) of the light transmission for each manufacturer, it can be seen that all the means are well within the stated requirement.

For the optical characteristic haze, we can state that the US-10 respirator is not significantly different from the Scott mask, but both US-10 and Scott are significantly different from ILC. Again, let us look at the mean haze from each manufacturer. We can see that the mean percent of haze is within the stated requirement. We can say that there is no practical difference among the manufacturers in the amount of haze from one week to the next.

For the third optical characteristic, Ann Arbor distortion, US-10 is not significantly different from ILC, but both are significantly different from Scott. From the means, we see that for all practical purposes, Ann Arbor distortion is no different from one manufacturer to the other. As in the inspection test, ILC and US-10 had little or no distortion, where as Scott had 34 out of 72 distortions at the 2 or 3 level.

The last optical characteristic, yellowness, is significant and the manufacturers are significantly different from each other. Since there is no criterion for this test, practical significance cannot be addressed.

Although light transmission, haze, and distortion had no practical significance as far as a difference between manufacturer, one may want to use this information to make a judgement regarding which manufacturer performs best over all the tests conducted.

TABLE 12. 9 WEEK STORAGE RESULTS

OPTICAL CHARACTERISTIC	MASK TYPE	MEAN	S.D.	SIGNIFICANT DIFFERENCE
Light Transmission	Scott	92.31	.33	ILC ≠ Scott ≠ US-10
	ILC	91.97	.37	
	US-10	92.56	.35	
Haze	Scott	.33	.15	(US-10 = Scott) ≠ ILC
	ILC	.68	.25	
	US-10	.29	.21	
Ann Arbor	Scott	1.68	.84	(US-10 = ILC) ≠ Scott
	ILC	1.03	.16	
	US-10	1.00	.00	
Yellowness	Scott	2.58	.78	US-10 ≠ Scott ≠ ILC
	ILC	5.21	1.53	
	US-10	1.76	.64	

D. RAM OPTICAL DATA - UNPACKAGED vs BOXED MASKS

Measurements on the optical characteristics (light transmission, haze, Ann Arbor distortion, and yellowness) were taken on 8 unpackaged masks and 4 boxed masks from each manufacturer. The test design is given below in Table 13.

TABLE 13. RAM OPTICAL DATA
UNPACKAGED vs BOXED

MASK TYPE	UNPACKAGED	BOXED
SCOTT	n = 8	n = 4
ILC	n = 8	n = 4
US-10	n = 8	n = 4

There are two factors of interest for each of the optical characteristics. These are type of packaging and manufacturer. The criteria are the same as stated previously in the CRDC optical data. Refer to Table 11. Using exploratory data analysis and analysis of variance, we found no significant difference between unpackaged and boxed masks for any of the optical characteristics. Therefore, boxed and unpackaged data were combined for comparison of the manufacturers. The results are shown in Table 14. Each optical characteristic will be discussed separately. For light transmission, ILC is significantly different from both Scott and US-10, but Scott and US-10 are not significantly different from each other. As seen in the CRDC optical data, the RAM data for light transmission falls within the stated criterion. Therefore, one may say that there are no practical differences among the manufacturers for light transmission.

For haze, the mean values for each manufacturer fall within the criterion, and there are no significant differences among the manufacturers.

All the manufacturers pass the criterion for Ann Arbor distortion, and there are no significant differences among the manufacturers.

There are significant differences in yellowness among the manufacturers. Both US-10 and Scott are significantly different from ILC, but they are not significantly different from each other. Since there is not a criterion for yellowness, practical significance cannot be addressed.

TABLE 14. UNPACKAGED vs BOXED RESULTS

OPTICAL CHARACTERISTIC	MASK TYPE	MEAN	S.D.	SIGNIFICANT DIFFERENCE
Light Transmission	Scott	92.09	.47	ILC ≠ (Scott = US-10)
	ILC	91.15	.44	
	US-10	92.42	.38	
Haze	Scott	2.20	1.87	(US-10 = Scott = ILC)
	ILC	2.62	1.44	
	US-10	1.21	.61	
Ann Arbor	Scott	1.29	1.35	(US-10 = Scott = ILC)
	ILC	1.38	1.30	
	US-10	1.00	.00	
Yellowness	Scott	3.13	.70	(US-10 = Scott) ≠ ILC
	ILC	9.36	3.62	
	US-10	2.13	.61	

E. OUTSERTS

Five pairs of outserts from each manufacturer were tested for light transmission before and after abrasion, and before and after storage. A pair consisted of one clear lens and one tinted lens. The test criteria are that a maximum of 23 percent and a minimum of 17 percent of daylight is to transmit the outsert. The results are shown in **Table 15**. The failures attributed to the tinted US-10 outserts is the over-transmission of daylight, i.e., more than 23 percent of light transmitted the outsert. The failures attributed to the tinted ILC outsert is the under-transmission of daylight, i.e., less than 17 percent of light transmitted the outsert. (NOTE: The number of masks before storage, after abrasion, is less then the number of masks after storage, after abrasion. The authors received no explanation for this discrepancy.)

F. CANISTER LIFE TESTS

Canisters were tested using two challenge agents GB and CK. Each agent was fixed at a concentration of 4.0 mg/L. The life requirement for the GB test is 110 minutes, and the life requirement for the CK test is 30 minutes. Nine canisters were tested with each agent during the baseline test phase. The results of the test revealed that all nine canisters passed the GB test but zero canisters passed the CK test.

Additional tests were performed during the RAM test phase. All 18 canisters from the CK test failed. The mean life was 19.30 with a standard deviation of 3.83. The results of the GB test are not available at this time.

Other tests were performed under various environmental conditions: outdoor exposure, storage, sunshine, rain, and dust. For the outdoor exposure and storage tests, only the CK agent test has been completed. All six canisters that were outdoor exposed

TABLE 15. RATIO OF SUCCESS OVER TOTAL SAMPLE FOR LIGHT TRANSMISSION ON OUTSERTS

Light Transmission Before Storage

	MASK	Before Abrasion	After Abrasion
CLEAR	Scott	5/5	2/2
	ILC	5/5	0/2
	US-10	5/5	1/1
TINTED	Scott	4/5	0/2
	ILC	1/5	0/2
	US-10	0/5	0/1

Light Transmission After Storage

	MASK	Before Abrasion	After Abrasion
CLEAR	Scott	5/5	5/5
	ILC	5/5	2/5
	US-10	5/5	5/5
TINTED	Scott	5/5	5/5
	ILC	1/5	0/5
	US-10	0/5	0/5

failed the CK agent test. The mean life was 24.17 minutes with a standard deviation of 2.56. Two out of four canisters under the storage conditions failed the CK agent test. One of these failures occurred at 29.5 minutes, which is close to the required life of 30 minutes. The mean life for the four canisters was 31.4 minutes with a standard deviation of 7.59.

The remaining tests, sunshine, rain, and dust were performed using both the GB and CK agent. Table 16 gives the passing rate, mean life, and standard deviation of the mean life for each agent.

TABLE 16. GB AND CK LIFE TESTS

AGENT		SUNSHINE	RAIN	DUST
GB	Pass Rate	3/3	2/3	0/3
	Mean	127.83	101.13	92.7
	St.Dev.	10.33	41.84	14.21
CK	Pass Rate	0/6	0/3	1/5
	Mean	21.52	27.13	27.04
	St.Dev.	35.13	1.85	4.35

G. VOICEMITTER AGENT TEST

Three medium masks were tested to see how resistant the voicemitters were against two toxic agents, HD and thickened GD. One mask was chosen from each manufacturer. The criterion states that each voicemitter must be resistant against the agents for at least 360 minutes. The results shown in **Table 17** below are the total minutes a voicemitter was resistant to an agent. The maximum time a voicemitter was tested was 1440 minutes (24 hours).

TABLE 17. VOICEMITTER AGENT TEST

TOXICOLOGICAL AGENT	MASK SCOTT	MASK ILC	MASK US-10
HD	10	1440	1440
TGD	1440	1440	1440

Only the Scott mask could not resist penetration of the HD agent. Since this was the only sample of the Scott mask under that agent, little can be said about the reliability of the Scott voicemitter.

H. NINE WEEK STORAGE (in boxes)

Masks from each manufacturer were stored in boxes for nine weeks. At the end of the nine weeks, three tests were performed; the DOP leakage test, and the inhalation and exhalation airflow resistance tests. Unlike the nine week storage for the optical data that were checked weekly, these masks were not checked until the conclusion of the nine weeks in storage. The results are shown for the tropic, desert, and cyclic climates in **Tables 18, 19, and 20**, respectively. The criteria for a success are .003% maximum leakage for the dioctal phthalate (DOP) test, 55 maximum resistance for the inhalation test, and 26 maximum resistance for the exhalation test.

TABLE 18. 9 WEEK STORAGE - TROPIC

TEST	MASK TYPE	F	S	N	R	L.C.L. on R. @ 80% CONF.
DOP	SCOTT	2	0	2	.00	.00
	ILC	0	2	2	1.00	.45
	US-10	2	0	2	.00	.00
INHALATION	SCOTT	0	2	2	1.00	.45
	ILC	0	2	2	1.00	.45
	US-10	0	2	2	1.00	.45
EXHALATION	SCOTT	0	2	2	1.00	.45
	ILC	0	2	2	1.00	.45
	US-10	0	2	2	1.00	.45

TABLE 19. 9 WEEK STORAGE - CYCLIC

TEST	MASK TYPE	F	S	N	R	L.C.L. on R. @ 80% CONF.
DOP	SCOTT	2	1	3	.33	.07
	ILC	0	3	3	1.00	.58
	US-10	3	0	3	.00	.00
INHALATION	SCOTT	0	3	3	1.00	.58
	ILC	0	3	3	1.00	.58
	US-10	3	0	3	.00	.00
EXHALATION	SCOTT	0	3	3	1.00	.58
	ILC	1	2	3	.67	.29
	US-10	0	3	3	1.00	.58

TABLE 20. 9 WEEK STORAGE - DESERT

TEST	MASK TYPE	F	S	N	R	L.C.L. on R. @ 80% CONF.
DOP	SCOTT	3	0	3	.00	.00
	ILC	0	3	3	1.00	.58
	US-10	3	0	3	1.00	.00
INHALATION	SCOTT	3	0	3	.00	.00
	ILC	1	2	3	.67	.29
	US-10	1	2	3	.67	.29
EXHALATION	SCOTT	0	3	3	1.00	.58
	ILC	0	3	3	1.00	.58
	US-10	0	3	3	1.00	.58

IV. REDESIGNED MASKS

A. US-10 RESPIRATOR

As previously mentioned, the US-10 respirator was redesigned to eliminate the leakage problem in the drink tube area. In particular, an improvement was made to the rubber formation of the shut-off valve and a modified spindle was incorporated. The manufacturer of the US-10 respirator, Avon, made the changes on the respirator and performed a series of leakage tests to verify its effectiveness on two prototype respirators. The two respirators went through the identical testing except one went through dry cycles, and the other went through wet cycles. First they went through 2500 cycles at a speed of 38 cycles per minute. Then the respirators were retested. Then they went through 10,000 cycles and tested at every 2500 cycle interval. Neither respirator experienced leakage. Therefore, a batch of 50 redesigned masks was made, and two respirators were randomly chosen and tested like the prototypes, one in the dry cycles and one in the wet cycles, except with more cycles to endure. The results show that only at the 25,000 cycles mark did the dry cycling indicate a leakage. (But 25,000 cycles was considered an extreme test.) The wet cycling showed no leakage up to and including 25,000 cycles. So combining this test with the prototypes, the leakage tests were considered a success. **Table 21** gives the point estimate of reliability and the lower confidence level on reliability at 80% confidence based on these preliminary results.

TABLE 21. PRELIMINARY LEAKAGE TEST ON REDESIGNED US-10

F	S	N	R	L.C.L. on R. @ 80% CONF.
0	4	4	1.00	.67

Although the point estimate on reliability is high, the lower confidence level is low. This is telling us that with this small sample size, we can only be 80% confident that the true reliability is at least 0.67. However, Avon performed additional testing on 30 respirators; 15 dry cycled and 15 wet cycled. The fifteen respirators under the dry cycle testing passed the leakage test for 20,000 cycles, but when they were tested for an additional 5,000 cycles, excessive wear of the rubber body caused leakages to all 15 respirators because of heat build-up. But again, 25,000 cycles was considered an extreme test. The fifteen respirators under the wet cycled testing experienced no leakages up to and including 25,000 cycles. The lower confidence limit on reliability at 80% confidence for the 4 preliminary tests combined with the additional 30 wet and dry tests passing at the 20,000 cycle mark is 0.95

B. REDESIGNED SCOTT LENS

Since too many failures occurred in the lens area of the Scott mask during the leakage tests, the mask was redesigned. A new series of tests was planned by the Mask Management Office and was agreed upon by the Test Engineer of the Material Evaluation Branch. The flowchart on the following page (Figure 1.) shows the tests to be performed to verify that the redesigned mask is reliable. All 22 masks passed the initial DOP leakage test. Eleven of these masks went into 9 weeks of storage while the other 11 masks went through rough handling tests that involved vibration, shock, and bounce. The 11 masks that went through the rough handling test were leak tested again and all 11 passed. Then these masks went through an accelerated 2 weeks of storage in four climates. Following the storage, all 11 masks passed the DOP leakage test.

The 11 redesigned Scott masks that went through 9 weeks of storage and rough handling had no failures. As a result, we can be 80% confident that the true reliability is at least .93. No additional testing of these masks is planned before going onto DT II/OT II. Some of the tests from the original test plan that were omitted from the testing of the redesigned masks are; adverse conditions, biological penetration,[1] and corn oil test.[2] How well the redesigned masks would have performed in these tests cannot be ascertained.

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[1] *The biological penetration of the Bacillus Globigii was performed by the CB Detection and Alarm Directorate which is now part of the Physical Protection Directorate. The writeup of this test can be found in "Reliability Assessment of the XM40 and S-10 Protective Mask Systems in Support of the Readiness For Test Review (RFTR)," PAD, RAM Engineering Branch, January 1985.*

[2] *Hughes, Brletich, and DiBerardo, "Mask Leakage Testing of Three Candidate Mask Systems in Support of the XM40 Engineering Design Test."*

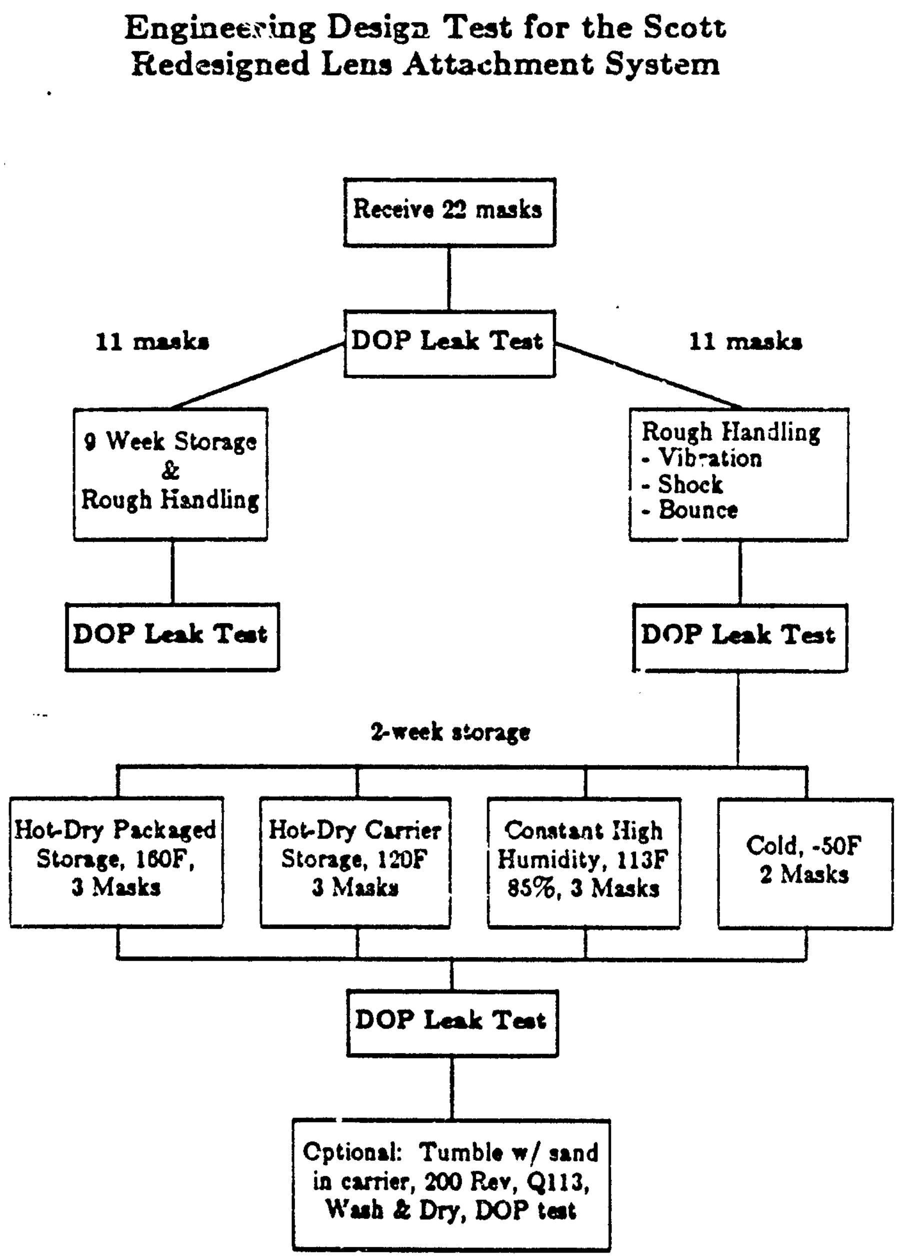

FIGURE 1. Engineering Design Test for the Scott Redesigned Lens Attachment System.

SUMMARY

Several problem areas have been identified from the analyses of the tests performed on the Scott and ILC masks, and the US-10 respirator. The most serious problems seem to have been corrected. Therefore, the Readiness For Test Review (RFTR) committee has decided to allow the masks to enter DT II/OT II testing. A summary of the problem areas are discussed below.

1. DOP LEAKAGE TESTS: The inspection DOP leakage test and the DOP leakage test after adverse conditions revealed a leakage problem in the lens area of the Scott mask and in the drink tube area of the US-10 respirator. These masks were redesigned to correct these leakages. The limited testing that has been completed on the redesigned masks has given some evidence that the problem has been corrected.

2. INHALATION: Only 50% of the US-10 aircraft respirators passed the inhalation airflow resistance test.

3. INHALATION AFTER ADVERSE CONDITIONS: The point estimates of reliability of all three mask types (Scott, ILC, and US-10), as a result of the inhalation resistance test after the adverse conditions (rain, salt-fog, sunshine, dust, and dust with DS2) were $\leq$ .77.

4. EXHALATION AFTER ADVERSE CONDITIONS: The exhalation resistance test after adverse conditions shows that the masks that underwent the rain environment without a carrier has the worst passing rate with a reliability of .67 and a lower confidence limit (L.C.L.) on reliability of only .29. This L.C.L. is partially due to the small sample size. Dust with DS2 is a potential problem. The reliability estimate is .83 but the L.C.L. on reliability is only .58.

5. OPTICAL DATA: The optical data from both the RAM test and CRDC's nine week storage test show that the manufacturers are significantly different in the amount of yellowness on the lenses. Since there is no criterion for yellow index, this may or may not have a practical significance.

6. OUTSERTS: Light transmission was performed on clear and tinted outserts before and after storage and before and after abrasion. Both the clear and tinted outserts of the ILC mask and US-10 respirator had a low success rate after abrasion before and after storage. Before abrasion, only the tinted ILC and US-10 outserts show a low success rate.

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